

Request for Information
Appendix 1

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
CENTENNIAL CHALLENGES PROGRAM**

**CUBESAT LUNAR
PROPULSION and COMMUNICATIONS
CHALLENGE**

OPERATIONS AND RULES

**For Public Release
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2.0 Introduction

The Centennial Challenges Program is NASA’s flagship program for technology prize competitions (www.nasa.gov/challenges). The program directly engages the public, academia, and industry in open prize competitions to stimulate innovation in technologies that have benefit to NASA and the nation. The Centennial Challenges Program is an integral part of NASA's Space Technology Mission Directorate, which is innovating, developing, testing, and flying hardware for use in NASA's future missions. For more information about NASA's Space Technology Mission Directorate, visit: <http://www.nasa.gov/spacetechnology>.

3.0 Challenge Overview

The CubeSat Lunar Challenge is designed to foster innovations in small spacecraft propulsion and communications techniques for small satellite systems. The Challenge will consist of a Ground Qualification Competition and in-space Lunar Propulsion and Communications Competitions. The spacecraft in these competitions must comply with standard CubeSat design specifications and will be 6U form factor. Specific Challenge requirements and prize allocations are defined in section 5.

This Challenge will award up to a total of \$3,000,000 in cash prizes to registered competitors that are able to meet or exceed technical objectives for 1) propulsion and 2) communication while in orbit around the Moon.

The Ground Qualification Competition Phase will be held to determine which competitors will be offered the opportunity for a NASA provided launch opportunity as a secondary payload on Exploration Mission -1 (EM-1), the first launch (EM-1) of NASA's Space Launch System (SLS) and Orion crew vehicle planned for Fiscal Year 2018. The CubeSats selected for the EM-1 flight will be deployed on a trans-lunar insertion trajectory. Up to a total of \$500,000 in cash prizes will be available in Ground Qualification Competition Phase.

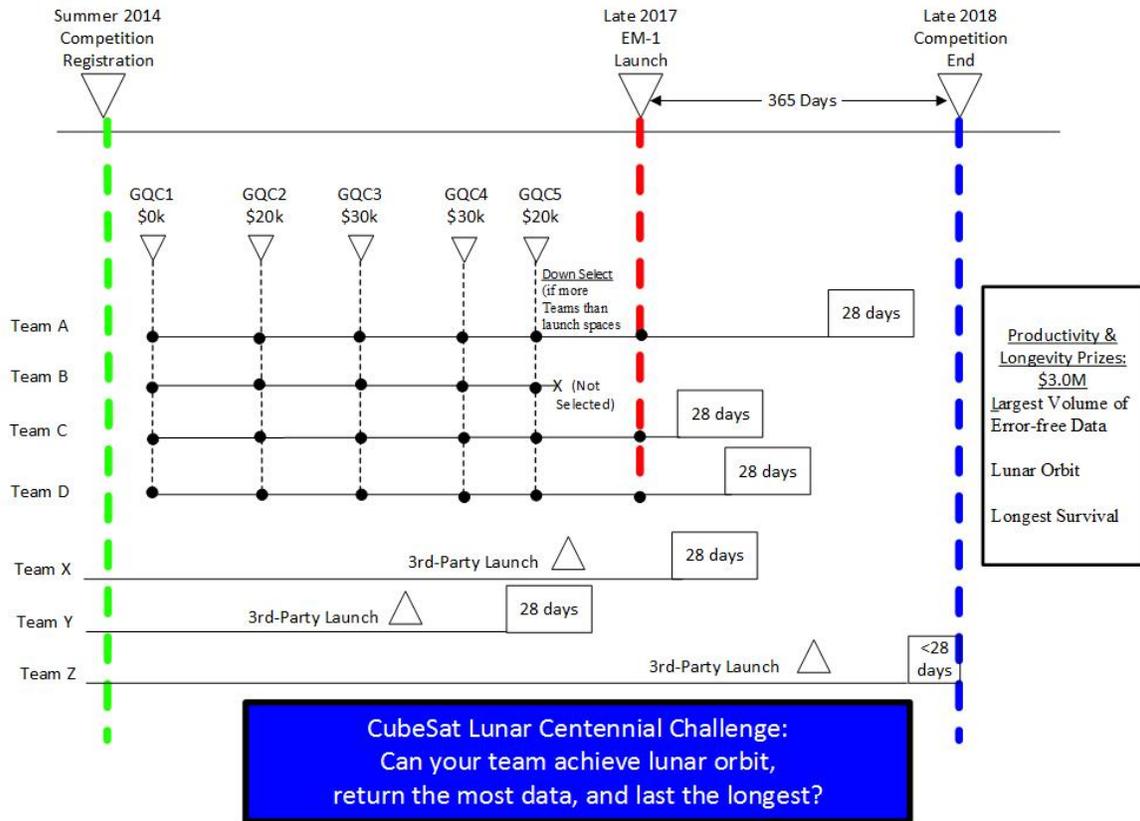
Registered competitors may also elect to use a non-NASA provided launch opportunity. Regardless of the launch vehicle used, the end of the Lunar Challenge will be determined by reference to the NASA-provided launch date and the results of all competitors will be considered at the end of competition to determine the winner(s). All competitors will be judged using the same criteria for the Lunar Propulsion and Lunar Communication Competitions. Competitors choosing to use a non-NASA launch are not eligible to participate in the Ground Qualification Competitions.

NASA will concurrently conduct the CubeSat Deep Space Communications Challenge that will award up to an additional \$1,500,000 in Prize Awards to registered competitors that are able to meet or exceed technical objectives for communication from at least ten times beyond the lunar distance. Specific requirements for that challenge are defined in the Rules document shown in Appendix 2 of this Request for Information.

Note that competitors may enter both Challenges but must use a single spacecraft and will have to meet all rules associated with the respective challenges in order to win a prize from each challenge.

4.0 Competition Phases

The two phases of the Lunar CubeSat Challenge are illustrated below. The Ground Qualification Competition consists of a series of five design reviews leading to selection of candidate CubeSats as EM-1 secondary payloads. The second phase is the in-space, Lunar Propulsion and Lunar Communication Competitions. In the figure, Teams A, B, C, and D all competed for a NASA-provided launch opportunity by participating in all reviews. Teams X, Y and Z used a third-party launch opportunity. Teams A, C, and D successfully participated in all reviews, were selected for flight, and conducted communications tests for 28 days during the challenge open period. Team B participated in all reviews but was not selected for flight so their participation ended at the GQC5. Teams X, Y and Z did not participate during the NASA reviews. These three teams were successfully launched by their third party providers. All reached lunar orbit and conducted communications tests within their respective eligibility windows and were eligible for challenge awards. Team Z started their tests less than 28 days from the end of the competition so they had fewer days to collect data than the other teams but they were the last team to communicate from lunar orbit.



4.1 In-Space Competitions

4.1.1 Lunar Propulsion Competition

The Lunar Propulsion competition will begin for each Team at the time of deployment of their respective CubeSats, and ends 365 days after their respective launch dates, or 365 days from the launch date of EM-1, whichever comes first (as defined in Section 5.3, Rule 10: *Lunar Propulsion and Lunar Communication Competitions End*).

NASA will award the following Lunar Propulsion Competition prize: the Lunar Propulsion Prize of \$1,500,000 will be divided equally between all Competitor Teams that establish a verifiable lunar orbit, as defined in Section 5.3, Rule 7: *Lunar Orbit Operations* and that are compliant with all other Rules.

4.1.2 Lunar Communications Competition

The Lunar Communications competition will begin after the competitor's CubeSat has established a verifiable lunar orbit as defined in the Rule 7 and ends 365 days after their respective launch dates, or 365 days from the launch date of EM-1, whichever comes first (as defined in Section 5.3, Rule 10: *Lunar Propulsion and Lunar Communication Competitions End*).

During the competition period competitors will acquire as much error-free data as they can from their CubeSat within single continuous 30-minute periods, and as much error-free data as they can within any 28-day period.

The competitor’s best data returns may be updated periodically on the Centennial Challenge website.

NASA will award the following Lunar Communication Competition prizes:

1. \$250,000 will be awarded to the Competitor Team that receives the largest cumulative volume of error-free data from their CubeSat over their best 30-minute period from lunar orbit before the end of competition.
2. \$750,000 will be awarded to the Competitor Team that receives the largest cumulative volume of error free data from their CubeSat over their best contiguous 28-day period from lunar orbit before the end of competition.
3. \$500,000 will be awarded to the last Competitor Team that receives the very last, error-free, 1024-bit data block from their CubeSat from lunar orbit at least 28 days after Start of Competition for their CubeSat and before the End of Competition.

4.2 Ground Qualification Competitions

The Ground Qualification Competitions consist of a series of ground-based activities, reviews and tests, leading up to selection of a limited number of spacecraft for integration and launch on EM-1. The purposes of the Ground Qualification Competitions are:

1. For NASA to gain insight into team designs of spacecraft and missions
2. To provide feedback to teams on progress and likelihood of success
3. To award intermediate prizes to teams, for promoting progress

Five reviews will take place. These are designated as 1) GQC1, 2) GQC2, 3) GQC3, 4) GQC4 and 5) GQC5. All competitors seeking a NASA launch opportunity on EM-1 must participate in all reviews in order to be considered for EM-1 integration.

Teams may elect to obtain their own third-party launches. Teams not launching on EM-1 must register for the competition, but are not eligible to participate in any of these reviews and therefore not eligible for any Ground Qualification Competition awards. These teams must also provide documentation prior to launch to the Judges showing that they meet the appropriate CubeSat form factor requirements. The Judges may also conduct inspections to verify submitted documentation.

NASA will award the following prizes for the Ground Qualification Competitions:

Ground Qualification Competitions	
COMPETITION	PRIZES
GQC1	None
GQC2	Five Highest Scoring Teams with scores greater than 3 will

	equally share \$100,000
GQC3	Five Highest Scoring Teams with scores greater than 3 will equally share \$150,000
GQC4	Five Highest Scoring Teams with scores greater than 3 will equally share \$150,000
GQC5	Five Highest Scoring Teams with scores greater than 3 will equally share \$100,000

During Ground Qualification Competitions, a panel of official Judges will use defined evaluation criteria to assess all review materials submitted by each team. See further details in Section 5.6 *Rules For Ground Qualification Competitions*.

4.3 CubeSat Payload Delivery, Integration, and Launch

Payload delivery for integration will take place between first and second quarter 2017. Payload integration with SLS will likely take place mid-2017. No access to the CubeSats will be allowed after integration. CubeSats will be inactive until after confirmation the Orion separation.

4.4 NASA-Furnished Resources

NASA will provide the following:

- Space Launch System Secondary Payload Deployment System Interface Definition and Requirements Document (IDRD) (Draft document expected August 2014 and Baseline document expected October 2014)
- SLS Secondary Payload User’s Guide (Draft document expected August 2014 and Baseline document expected October 2014)
- Software source code for generation of data for the Lunar Communications Competition. (Baseline document expected October 2014)

5.0 Competition Rules and Requirements

Rule 1: Eligibility to Compete

Rule 1.A: Teams that include foreign nationals who are not permanent residents of the United States shall not be accepted for these Challenge competitions. The sole exception is for U.S based educational institutions, which may have up to 50% foreign national students on their teams.

Rule 1.B: No Team member shall be from a country on the NASA Export Control Program list of designated countries. (The current list of designated countries can be found at <http://oir.hq.nasa.gov/nasaecp/>).

Rule 1.C: Teams shall not include any Federal entity or Federal employee acting within the scope of their employment. This includes any U.S. Government organization or organization principally or substantially

funded by the Federal Government, including Federally Funded Research and Development Centers, Government-owned, contractor operated (GOCO) facilities, and University Affiliated Research Centers.

Rule 1.D: Teams are responsible for compliance with all applicable regulations and laws including obtaining any necessary approvals for foreign student participation.

5.1 Registration

Rule 2: Prospective competitors shall submit a registration package to NASA including a signed competitor Team Agreement and initial details of their CubeSat concept(s) along with the designation of the controlling organization for the purposes of communication licensing, in order to compete in the CubeSat Lunar Challenge. The registration package shall be submitted to NASA through the NSPIRES document submission site. (<http://nspires.nasaprs.com/external/>). See the site for information on how to register for NSPIRES access. The prospective competitor will receive formal acknowledgement of the receipt of their package within 5 business days of submittal and formal acceptance as Challenge Competitors within 15 business days.

5.2 Design

Rule 3: Specifications

Rule 3.A: To be eligible for NASA EM-1 Launch, Competitor's CubeSat and CubeSat Dispenser shall meet the Space Launch System Secondary Payload Deployment System Interface Definition and Requirements Document (IDRD). In the event of a conflict between the SLS IDR and these Competition Rules, the SLS-IDRD shall take precedence.

Rule 3.B: For non-EM-1 launches, CubeSats shall be of a 6U form factor.

Rule 3.C: No deviations from the 6U form factor will be permitted.

Rule 3.D: Non EM-1 launch competitors will be responsible for determining, and complying with, their own respective responsibilities and requirements with the third-party launch vehicle provider. NASA will not assist with compliance with third party launch provider requirements.

Rule 4: Radio Frequency Authorization

Rule 4.A: Competitors agree that use of Radio Frequencies (RF) for the tracking and control of the spacecraft and for the transmission of information (data) to and from the spacecraft will be in accordance with all U.S. laws and regulations, and with the International Radio Regulations promulgated by the International Telecommunications Union (ITU). The controlling organization for each cubesat shall obtain radiofrequency authorization from the Federal Communications Commission (FCC) in accordance with the Rules

and Regulations, Title 47, of the Code of Federal Regulations. FCC Public Notice DA: 13-445 (<http://www.fcc.gov/document/guidance-obtaining-licenses-small-satellites>) is useful in deciding authorization options to consider.

Rule 4.B: For all required communications, any Radio Frequency or Optical Frequency is allowed, subject to all applicable RF licensing and spectrum allocation rules.

Rule 4.C: Competitors are responsible for obtaining necessary RF operating licenses for both their CubeSat space stations and for all ground stations used, and are responsible for abiding by National and International rules governing radio operators in the spectrum in which they operate.

Rule 5: Monitoring and Site Visits

Rule 5.A: NASA reserves the right to non-invasively monitor any communication relevant to the competitions using NASA's resources without permission of the Competitors. This monitoring may be used to verify compliance with the Challenge Rules and may be used to determine winning Competition teams.

Rule 5.B: NASA may request visits to Competitors' operations sites, and request inspection of ground equipment and operating procedures. Visits may be used to verify compliance with the Challenge Rules.

5.3 General Rules for Lunar Propulsion and Lunar Communications Competitions

Rule 6: EM-1 Deployment Trajectory

Rule 6.A: NASA shall provide planned Earth-centric orbital elements that are expected immediately after the upper stage disposal maneuver, by a date no later than the GQC3 milestone.

Rule 6.B: NASA shall confirm or revise actual orbital elements within 24 hours after the IPCS disposal maneuver is actually performed.

Rule 7: Lunar Orbit Operation

Rule 7.A: For the purpose of this competition, a lunar orbit is defined as at least one orbit of minimum distance always above the lunar surface of 300 km, and with an aposelene that never exceeds 10,000 km.

Rule 7.B: Competitor Teams must provide evidence that demonstrates, to the satisfaction of the Judges, that they have successfully achieved a lunar orbit, as defined in this document. (Acceptable evidence could be Doppler ranging data from third party ground stations, star tracker data, a series of photographic images of the lunar surface, with verifiable time stamps and using optics of verified design, that Judges are able to confirm were photographed over the duration of at least one CubeSat orbital period, or other pertinent data.)

Rule 7.C: Competitor Teams must provide evidence that demonstrates, to the satisfaction of the Judges, successful achievement of transmission of their data from lunar orbit and receipt by their ground station. Raw data shall be made available to the Judges at the same time as the team. Judges shall also receive contact logs from the ground station operators. Logs are to include pointing data, AZ/EL coordinates, and receiver start/stop times.

Rule 7.D: Missions must maintain a minimum altitude of at least 300 km above the lunar surface at all times, before intentional end-of-mission disposal maneuvers.

Rule 7.E: CubeSats shall maintain a lunar orbit with an apselene less than 10,000 km at all times, during any operations that would count toward competition achievements.

Rule 7.F: Missions must include sufficient design capability to execute an “end of mission” maneuver to enter a disposal orbit or controlled deorbit to the lunar surface. Lunar impact must comply with “NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of U.S. Government Lunar Artifacts” found at http://www.nasa.gov/sites/default/files/617743main_NASA-USG_LUNAR_HISTORIC_SITES_RevA-508.pdf

Rule 8: Competitor Ground Stations

Rule 8.A: Competitors may communicate with, and update, their CubeSat as often as desired within the competition period. This includes commands, revised operating instructions, or software updates, etc.

Rule 8.B: Transmission and reception on Earth may be from the same ground station or differing ground stations.

Rule 8.C: Government controlled stations shall not be used unless appropriate compensation is provided and the station is also made available under the same terms to all Competitor Teams.

Rule 8.D: Ground stations may either belong to a Competitor Team or may be acquired or leased.

Rule 9: Lunar Propulsion and Communication Competition Start

Rule 9.A: For Competitor Teams that have arranged their own third party launches, the lunar propulsion competition shall begin at immediately after they are deployed by their respective launch provider. Teams shall notify Judges within 1 hour of their receipt of positive confirmation of their time of deployment.

Rule 9.B: For CubeSats deployed from SLS on EM-1, the lunar propulsion competition shall begin immediately after their CubeSat is deployed.

Rule 9.C: For each Competitor Team, the Lunar Communication Competition shall begin at the time their respective CubeSat has established a verifiable lunar orbit. (Verifiable lunar orbit is defined in Rule 7).

Rule 10: Lunar Propulsion and Lunar Communication Competitions End

Rule 10.A: For Competitor Teams that have arranged their own third party launch, competition shall end 365 days after they are deployed by their launch provider, or 365 days after EM-1 has deployed the EM-1 CubeSats, whichever occurs first.

Rule 10.B: For all other CubeSats, the Lunar Propulsion and Lunar Communications competitions end at 12:00 GMT, 365 days after EM-1 has deployed the EM-1 CubeSats.

Rule 10.C: No activity that takes place more than 365 days after the EM-1 CubeSat deployment shall be counted for the purposes of this Challenge, regardless of the respective launch dates.

Rule 10.D: In the event that no CubeSat successfully achieves lunar orbit (as defined) within 365 days of their launch, NASA will declare the competitions over with no winner and no prizes awarded.

Rule 10.E: If, for any reason, a CubeSat does not successfully deploy from EM-1 SLS (a dispenser malfunction, for example), then that team will be ineligible for the Lunar Propulsion and Lunar Communications prizes.

5.4 Additional Rules for Lunar Propulsion Competition

Rule 11: Lunar Propulsion Competition Goal and Prize

All Competitor Teams that successfully demonstrate their CubeSat has achieved a verifiable lunar orbit before the End of Competition shall be awarded an equal share of the \$1,500,000 Lunar Propulsion Competition Prize. (Verifiable lunar orbit is defined Rule 7. End of Competition is defined in Rule 10.)

5.5 Additional Rules for Lunar Communications Competition

Rule 12: Definitions

Rule 12.A: Error free communications are determined by the number of whole data blocks delivered to the Judges that are free of transmission errors. Competitor Teams may employ any error correction protocols (FEC, ARQ, hybrids) of their choice to achieve error-free delivery of data.

Rule 12.B: A data block is 1024 bits of random data generated by a NASA-provided algorithm using a seed value prescribed by NASA.

Rule 12.C: An operating period is a continuous 30-minute time segment during which the Competitor Teams will officially attempt to receive data.

Rule 13: Lunar Communications Competition Goal and Prizes

Rule 13.A: The Team that receives the largest error-free volume of data from their CubeSat over the Team's chosen, best, 30-minute period, from lunar orbit, before the End of Competition, shall be awarded a prize

amount of \$250,000. In case of a tie, all teams will receive an equal portion of this prize amount.

Rule 13.B:The Team that receives the largest error-free cumulative volume of data from their CubeSat aggregated over the Team's chosen, best contiguous 28-day period, from Lunar orbit, before the End of Competition, shall be awarded a prize amount of \$750,000. In case of a tie, all teams will receive an equal portion of this prize amount.

Rule 13.C: The last Team that receives the very last, error-free, 1024-bit data block (as defined in Rule 12.B) from their CubeSat from Lunar orbit, at least 28 days after Start of Competition, and before the End of Competition, shall be awarded a prize amount of \$500,000. The prize will be awarded once no more transmissions are received from any CubeSat over a span of 28 consecutive days (i.e., 28 days after the last CubeSat heard from). If the last transmission of error-free data occurs less than 28 days after Start of Competition, then this Award is void. In case of a tie, all teams will receive an equal portion of this prize amount.

Competitor Teams shall provide verifiable evidence to Judges (Rule 7) to demonstrate actual distances and communication achieved. End of Competition is defined in Rule 10.

Rule 14: Lunar Communications Competition Procedure

Rule 14.A: Each Competitor Team shall inform Judges, by 22:00 UTC each day, that the Team intends to participate in the Lunar Communications Competition, of the number and start times for the operating periods to be utilized for the next 24 hours beginning at 00:00 UTC the next day. If the Competitor Teams announces no operating periods, then Judges will not count any operations that day for the purposes of the Competition.

Rule 14.B:Judges shall deliver the random number seed for each operating period to the contestant Team over the Internet within <TBD> minutes prior to the start of the operating period.

Rule 14.C: The Competitor Team shall transmit the seed value to their CubeSat no sooner than the start of the operating period.

Rule 14.D: The Competitor Team shall supply a CubeSat communications log to the Judges to verify Competition timing.

Rule 14.E:The CubeSat shall use the NASA provided random number generator code to generate 1024-bit blocks of data and transmit the blocks to the Competitor Team ground station receiver. (Competitor Teams may choose to wrap data blocks in a convenient protocol for transmission to assist with block accounting and sequencing.)

Rule 14.F: Competitor Team shall receive the data blocks over the communications link, perform any required error correction deemed necessary, and arrange the blocks in correct sequence. Any blocks

that are not completely received within the operating period will not count towards the total for that operating period.

Rule 14.G: The Competitor Team shall deliver properly sequenced, error-free data blocks that they receive at the ground station to the Judges within TBD minutes of the close of the operating period. If the Contestant team requires a data retransmission to achieve an error-free block, the Contestant team must complete that transaction by the end of the operating period.

5.6 Rules for Ground Qualification Competition

5.6.1 Ground Qualification Competition Constraints

Teams seeking a secondary payload assignment on EM-1 must participate in all reviews, to be considered eligible for launch on EM-1.

Registered teams that arrange for independent, third-party launches are not eligible to participate in any Ground Qualification Competition reviews and are therefore not eligible for any Ground Qualification Competition Prizes, nor will they receive any feedback from Judges or NASA Mission Design Centers.

5.6.2 Procedures for Ground Qualification Competition

Reviews may be held through telecons, site visits, and co-located reviews. Reviews will typically be approximately three hours duration. Documents for reviews will be due two weeks in advance of each review. Review templates will be provided as appropriate.

5.6.2.1 Rules and Requirements for GQC1 Competition

The purpose of the GQC1, to be held in Q1 CY2015, is to introduce mission objectives, requirements definition, design concepts, and program feasibility.

Rule 15: Participation in the GQC1 is required for eligibility for selection, integration and deployment on EM-1.

To participate in the GQC1 and be eligible for selection, integration and deployment on the EM-1 Mission, Competitor Teams shall provide to Judges the following:

- Concept of Operations and Conceptual Mission Design
- Conceptual method for CubeSat disposal.
- Key Performance Parameters List and Values (up to five, at least one KPP must be communications performance related)
- Preliminary Project Schedule
- Preliminary Frequency Allocation Data Package
- Initial self-assessments of CubeSat conceptual design against the Verification requirements of the SLS Secondary Payload Deployment System IDR, along with list of any concerns or questions about potential compliance.

The items listed here are *candidate* Key Performance Parameters (KPPs):

- Delta V capability
- Mass Fraction
- Propulsion thrust
- Pointing of Directional Elements (antenna boresight, thrust direction, etc.)
- Standard parameters in Link Budget Calculations
- Expected “view” time of each ground station
- Other factors such as, expected coded and un-coded Bit Error Rate, link margins for coded and uncoded Eb/No, and margin for the minimum power at the input to the ground station receiver.

Rule 16: Judging

Judges will consult with a NASA design center and/or third-party expert consultants, run mission simulations and analysis using KPP performance projections submitted by each team. Judges will provide feedback to Teams on their mission and spacecraft design. No prizes shall be awarded in the GQC1.

5.6.2.2 Rules and Requirements for GQC2 Competition

The GQC2, to be held in Q3 CY2015, is a review of the teams’ initial design (subsystems, interfaces, configuration items) relative to the requirements specified in this document and the SLS Secondary Payloads IDR interface and safety requirements.

Rule 17: Only Competitor Teams that participate in the GQC2 shall be eligible for GQC2 Prize Awards. Participating in the GQC2 is required for eligibility for selection, integration and deployment on EM-1.

To participate in the GQC2 Competitor Teams shall provide to Judges the following:

- Updated Concept of Operations and Conceptual Mission Design
- Preliminary Verification Matrix of the Space Launch System Secondary Payload Deployment System Interface Definition and Requirements Document (IDRD)
- Project Schedule—Status
- Preliminary Subsystem Drawings
- Preliminary Mass, Volume, Power, Link, and Computing Budgets and Margins
- Preliminary Materials List for Components
- Preliminary Structural, Thermal, Pressure Profile & Electromagnetic Compatibility (EMC) Analyses/ Models
- Prototype Hardware (optional)
- Draft Frequency Allocation Data Package

Rule 18: Judging

Judges will consult with a NASA design center and/or third-party expert consultants, run mission simulations and analysis using KPP performance projections submitted by each team. Judges will assess if competitors are on track, and provide feedback to Competitor Teams. Judges will evaluate the CubeSat for selection as an EM-1 secondary payload based on probability of mission success and compliance with competition requirements. Five Highest Scoring Teams with scores greater than 3 will equally share \$100,000.

Rule 18.A: Probability of Mission Success (40%)

Judges shall consider the following when assessing the CubeSat probability of mission success:

- Ability to successfully meet the minimum requirements for the Lunar Propulsion and Lunar Communication Competitions. Based on Design Center evaluations, KPP assessments, updated concepts, fidelity of models, and budget margins, Judges will award scores 1 (very low likelihood) to 5 (very high likelihood) on ability to meet minimum requirements for the competitions.
- Ability to survive the launch and on-orbit environments. Based on assessment of structural design, materials and components selected, Judges will award scores of 1 (very low likelihood) to 5 (very high likelihood) on ability to survive the launch and on-orbit environments.

Rule 18.B: Requirements Verification Management (60%)

Judges shall consider the following when evaluating Competitor Teams for Requirements Verification Management:

- Compliance with SLS Secondary Payload Deployment System IDRD safety and interface requirements (ground and flight) (1, non-compliant, to 5, fully compliant)
- Compliance with the other Challenge requirements. (1, non-compliant, to 5, fully compliant)
- Projected ability to successfully complete the SLS launch vehicle safety review, Integration and Testing (I&T), and launch processes (1, very low likelihood, to 5, very high likelihood)

5.6.2.3 Rules and Requirements for GQC3 Competition

The GQC3 will be held in Q1 CY2016. GQC3 includes a review of design drawings and is an opportunity to assess the design with regard to maturity, risk, compliance with requirements, etc. In addition to drawings, teams are expected to have completed CubeSat and subsystem assembly procedures, updated system and subsystem analyses, and results of subsystem level testing.

Rule 19: Only contestant Teams that participate in the GQC3 shall be eligible for GQC3 Prize Awards. Participation in the GQC3 is required for eligibility for selection, integration and deployment on EM-1.

To participate in the GQC3, Competitor Teams shall provide to Judges the following:

- Updated Concept of Operations and Conceptual Mission Design
- Updated Verification Matrix of the SLS Secondary Payload Deployment System IDRD
- Project Schedule—Status
- System and Subsystem Drawings (90-95% complete)
- Mass, Volume, Power, Link, and Computing Budgets and Margins
- Structural, Thermal, Pressure Profile & EMC Analyses/ Models
- Materials List for Components
- Prototype Hardware (optional)
- Frequency Allocation Data Package
- Preliminary Integration and Test Plans
- Preliminary Safety Data Package (template and data requirements to be provided to the competitors no later than GQC2)

Rule 20: Judging

Judges will consult with a NASA design center and/or third-party expert consultants, run mission simulations and analysis using KPP performance projections submitted by each team. Judges will assess if competitors are on track, and provide feedback to Competitor Teams. Judges will evaluate the CubeSat for selection as an EM-1 secondary payload based on probability of mission success and compliance with competition requirements. Five Highest Scoring Teams with scores greater than 3 will equally share \$150,000.

Rule 20.A: Probability of Mission Success (40%)

Judges shall consider the following when assessing the CubeSat probability of mission success:

- Ability to successfully meet the minimum requirements for the Lunar Propulsion and Lunar Communication Competitions. Based on Design Center evaluations, KPP assessments, updated Concepts, fidelity of models, and budget margins, Judges award scores 1 (very low likelihood) to 5 (very high likelihood) on ability to meet minimum requirements for the competitions.
- Ability to survive the launch and on-orbit environments. Based on assessment of structural design, materials and components selected, Judges award scores of 1 (very low likelihood) to 5 (very high likelihood) on ability to survive the launch and on-orbit environments.

Rule 20.B: Requirements Verification Management (60%)

Judges shall consider the following when assessing the Competition Teams for Requirements Verification Management:

- Compliance with Space Launch System Secondary Payload Deployment System Interface Definition and Requirements Document (IDRD) safety

and interface requirements (ground and flight) (1, non-compliant, to 5, fully compliant)

- Compliance with the other Challenge requirements. (1, non-compliant, to 5, fully compliant)
- Projected ability to successfully complete the SLS launch vehicle safety review, I&T and launch processes (1, very low likelihood, to 5, very high likelihood)

5.6.2.4 Rules and Requirements for GQC4 Competition

The GQC4 will be held in Q4 CY2016. The GQC4 is a review of the spacecraft build process and subsystem- and system-level performance testing. All analyses and system models should be complete, as well as system assembly procedures. Drawing documentation should be complete, and should reflect the as-built configuration. The preliminary environmental test plan, operational test plan, and on-orbit operations plan will be evaluated.

Rule 21: Only Competitor Teams that participate in the GQC4 shall be eligible for GQC4 Prize Awards. Participation in the GQC4 is required for eligibility for selection, integration and deployment on EM-1.

To participate in the GQC4, Competitor Teams shall provide to Judges the following:

- Updated Concept of Operations and Conceptual Mission Design
- Updated Verification Matrix of the Space Launch System Secondary Payload Deployment System Interface Definition and Requirements Document (IDRD)
- Project Schedule—Status
- System and Subsystem Drawings (complete)
- Mass, Volume, Power, Link, and Computing Budgets and Margins
- Complete Materials List for Components
- Subsystem test results (particularly for Communications subsystem, Propulsion subsystem, Attitude Control Subsystem, and deployable mechanisms test results)
- Environmental Test Plan
- Functional and Acceptance Test Plan
- Updated Structural, Thermal, Pressure Profile & EMC Analyses/ Models
- Prototype CubeSat (optional)
- Completed Frequency Allocation Data Package.
- Final Safety Data Package/Hazard Analysis

Rule 22: Judging

Judges will consult with a NASA design center and/or third-party expert consultants, run mission simulations and analysis using KPP performance projections submitted by each

team. Judges will assess if competitors are on track, and provide feedback to Competitor Teams. Judges will evaluate the CubeSat for selection as an EM-1 secondary payload based on probability of mission success and compliance with competition requirements. Five Highest Scoring Teams with scores greater than 3 will equally share \$150,000.

Rule 22.A: Probability of Mission Success (40%)

Judges shall consider the following when assessing the CubeSat probability of mission success:

- Ability to successfully meet the minimum requirements for the Lunar Propulsion and Lunar Communication Competitions. Based on Design Center evaluations, KPP assessments, updated Concepts, fidelity of models, and budget margins, Judges award scores 1 (very low likelihood) to 5 (very high likelihood) on ability to meet minimum requirements for the competitions.
- Ability to survive the launch and on-orbit environments. Based on assessment of structural design, materials and components selected, Judges award scores of 1 (very low likelihood) to 5 (very high likelihood) on ability to survive the launch and on-orbit environments.

Rule 22.B: Requirements Verification Management (60%)

Judges shall consider the following when assessing the Competitor Team for Requirements Verification Management:

- Compliance with SLS Secondary Payload Deployment System IDR safety and interface requirements (ground and flight) (1, non-compliant, to 5, fully compliant)
- Compliance with the Centennial Challenge requirements. (1, non-compliant, to 5, fully compliant) Note that non-compliance with some pre-requisite Centennial Challenge requirements (Registration requirements, for example) could disqualify teams at the level of this review.
- Projected ability to successfully complete the SLS launch vehicle safety review, I&T and launch processes (1, very low likelihood, to 5, very high likelihood)

5.6.2.5 Rules and Requirements for GQC5 Competition

The GQC5 will be held in Q1 CY2017 is a required review for all teams to be considered for integration and launch on EM-1. The final review is to determine which teams can deliver a CubeSat that can successfully demonstrate at least the minimum performance criteria to qualify for a prize, while also meeting SLS interface and safety requirements.

Rule 23: Only Competitor Teams participate in the GQC5 shall be eligible for GQC5 Prize Awards. Only Competitor Teams that pass the GQC5 shall be eligible for selection, integration and deployment on EM-1.

To participate in the GQC5, Competitor Teams shall provide to Judges the following:

- Final Mission Operations Plan
- Final Verification Matrix of the Space Launch System Secondary Payload Deployment System Interface Definition and Requirements Document (IDRD)
- Project Schedule to Integration
- System and Subsystem Drawings (complete)
- Final Mass, Volume, Power, Link, and Computing Budgets and Margins
- System-level test results (particularly for Communications subsystem, Propulsion subsystem, Attitude Control Subsystem, and deployable mechanisms test results)
- Environmental Test results
- Final Structural, Thermal, Pressure Profile & EMC Analyses/ Models
- Flight CubeSat (optional)
- Completed Frequency Coordination Documentation
- Final Safety Verification

The Competitor Teams shall provide the final analysis to show that the proposed method for CubeSat disposal meets all challenge requirements.

Rule 24: Judging

Judges will consult with a NASA design center and/or third-party expert consultants, run mission simulations and analysis using KPP performance projections submitted by each team. Judges will evaluate the CubeSat for selection as an EM-1 secondary payload based on probability of mission success and compliance with competition requirements. Five Highest Scoring Teams with scores greater than 3 will equally share \$100,000.

Rule 24.A: Probability of Mission Success (40%)

Judges shall consider the following when assessing the CubeSat probability of mission success:

- Ability to successfully meet the minimum requirements for the Lunar Propulsion and Lunar Communication Competitions. Based on Design Center evaluations, KPP assessments, updated Concepts, fidelity of models, and budget margins, Judges award scores 1 (very low likelihood) to 5 (very high likelihood) on ability to meet minimum requirements for the competitions.
- Ability to survive the launch and on-orbit environments. Based on assessment of structural design, materials and components selected, Judges award scores of 1 (very low likelihood) to 5 (very high likelihood) on ability to survive the launch and on-orbit environments.

Rule 24.B:Requirements Verification Management (60%)

Judges shall consider the following when assessing the Competitor Team for Requirements Verification Management:

- Compliance with SLS Secondary Payload Deployment System IDR safety and interface requirements (ground and flight).
- Compliance with other Challenge requirements. (1, non-compliant, to 5, fully compliant)

Rule 25: Only Competitor Teams that receive a GQC5 score of at least 3 and are in compliance with all Challenge requirements including the SLS Secondary Payload Deployment System IDR safety and interface requirements (ground and flight) will be qualified for integration, launch, and deployment on the EM-1 mission.

5.6.3 Down Select Launch Candidates (conditional) - 2017

Rule 26: In the case that, upon the outcome GQC5, the total number of qualified CubeSats exceeds the available number of SLS secondary payload slots allocated to the Lunar CubeSat Challenge, then the following Down-Select Rules shall apply:

Rule 26.A: Judges shall award 1 point for each 10% above the minimum KPP.

Rule 26.B:Judges shall rank all Competitor Teams in order based on the total score of points awarded under Down-Select Rules.

Rule 26.C: The top n <TBD> ranked Competitor Teams shall be selected for integration with the n <TBD>SLS Secondary Payload dispenser slots available to the Centennial Challenge.

Rule 26.D: The next (n + 1) ranked Competitor Team (the “runner-up”) shall integrate with EM-1 in case any of the selected teams becomes unavailable for vehicle integration for any reason, between the time of selection and the actual vehicle integration date.